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Avinash Tiwari
Research scholar, Department of Physiotherapy, Guru Nanak Dev University, Amritsar, Punjab, India

Nihar Ranjan Mohanty
Research scholar, Department of Physiotherapy, Guru Nanak Dev University, Amritsar, Punjab, India

Shyamal Koley
Professor and Head, Department of Physiotherapy, Guru Nanak Dev University, Amritsar, Punjab, India

Debasish Panda
Physiotherapist, Jharkhand State Cricket Association, Jharkhand, India

Correspondence
Nihar Ranjan Mohanty
Research scholar, Department of Physiotherapy, Guru Nanak Dev University, Amritsar, Punjab, India

Estimation of foot arch and injury patterns in state level runners

Avinash Tiwari, Nihar Ranjan Mohanty, Shyamal Koley and Debasish Panda

Abstract
The Purposes of the study was to determine whether male and female high-arched and low-arched runners exhibit different injury patterns and to establish correlation of foot arch with Q-angle. High arched (HA) and low arched (LA) runners with their different bony structure may show different lower extremity mechanics and different injury patterns. The Q-angle is also to be altered with different foot structures. It was hypothesized that HA runners would exhibit a larger incidence of lateral injuries, skeletal injuries and knee injuries while LA runners would show medial injuries, soft tissue injuries and foot injuries. A total of 103 high-arched and low-arched runners of both sexes (male=50, female=53) were included in this study. Subjects completed a self administered injury history questionnaire in which they mentioned all running related lower extremity injuries. All injuries were categorized into three groups: (i) injury patterns of medial/lateral, (ii) bony/soft tissue, (iii) knee, ankle and foot. Results showed that LA runners had more soft tissues, medial side and knee injuries. LA females were having higher foot height than male and HA group males were having larger arch height-length ratio than females. Range of Q-angle changes according to foot structure types. Based on these results, HA and LA foot structure is associated with different lower extremities injuries pattern in runners. Range of Q-angle changes according to foot structure types. Significant differences are seen in arch height in LA males and females; and arch index in HA males and females runners.

Keywords: Runners, high arch, low arch, Q-angle, arch index, arch height

Introduction
Foot structure is commonly associated with lower extremities problems. The bony shape, the ligaments of the foot, and the muscular tones all play an important role in supporting the arches. It is believed that many factors play roles in the development of injuries in the lower extremities of runners. Injuries are often reported to be due to overuse (Pollock *et al*., 1977; Koplan *et al*., 1982) [12, 9] and lower extremities mechanics are thought to play a role (James *et al*., 1978; McClay, 1997) [8, 11]. Due to repeated loading of the lower extremities, risk of overuse injury among athletes is high. Individuals with normal arch (NA) structure compared to those with high (HA) or low arch (LA) may be at increased risk of specific overuse injuries, including stress fractures.

Abnormal structure has been described as a factor that increases risk for injury (Gross, 1992; Hamil *et al*., 1992) [5, 6]. Giladi *et al*. (1985) [4] demonstrated that high-arched (HA) or normal arched subjects were more likely to develop stress fractures than low-arched (LA) people. Similarly, Cowan *et al*. (1993) [1] described that HA individuals had the greatest possibility toward injuries of the lower extremities when compared to a runners with normal and LA structures. LA subjects demonstrate a greater number of metatarsal injuries while HA individuals are reported to have an increased number of tibial femoral stress fractures (Simkin *et al*., 1989) [13]. It was found that both HA and LA patients had greater incidences of knee injuries than patients with normal arch structure (Dehle *et al*., 1991) [2].

It has been reported that a pronated or planus foot puts load to the medial foot while a HA runners tends to put load to the lateral structures more (Subotnick and Sisney, 1986) [14]. Runners with planus or LA feet may develop more medial foot and lower extremity problems and more lateral problems occur those with cavus or HA feet.

Runners with high medial longitudinal arch structure demonstrate unique kinematics and kinetics that may lead to running injuries.

The mobility of the mid-foot as measured by the change in arch height is also suspected to play a role in lower extremity function during running. The effect of arch mobility in high-arched runners is an important factor in prescribing footwear, training, and rehabilitating the running athlete after injury (Williams III *et al*. 2001) [16].

Therefore, the purpose of this study was to determine the injury patterns associated with different foot arch structure, to determine the range of Q-angle changes and to determine the foot structure differences between males and females runners. The structural differences in foot structure between males and females exhibit different foot mechanics. The Q-angle is also to be altered with different foot structures. It was hypothesized that High-arched runners will exhibit a larger incidence of lateral injuries, skeletal injuries and knee injuries while low-arched runners will show medial injuries, soft tissue injuries and foot injuries.

Methodology

The data was collected under natural environmental conditions from a total of 103 (male=50, female=53) high-arched and low-arched state level runners including short, middle and long distance of both sexes between the ages of 16-30 years selected purposively from different districts of Odisha. Subjects were excluded if they were recently injured, ACL deficient or recent lower extremities surgery within the past 06 months. All subjects had a history of running-related lower extremities injury.

A written consent was obtained from the subjects prior to the study. Subjects completed a self administered injury history questionnaire, in which they mentioned all running related lower extremity injuries. All injuries had been previously diagnosed by medical professionals and physiotherapists. All injuries were categorized into three groups: (i) injury patterns of medial/lateral, (ii) bony/soft tissue, (iii) knee/ankle and foot. An injury could fall into more than one category. For example, a lateral ankle sprain would be considered lateral, soft tissue and ankle. The injury type, which was not fallen into listed injury conditions in questionnaire, those has been categorized in others type. The tools for data collection were anthropometric rod, weighing machine, tray with diluted ink, graph sheet, metal ruler, and universal goniometer. The parameters measured were truncated length of foot, height of the arch of the foot, and Q- angle.

After collecting data of all running related lower extremity injuries, subjects were then screened with the use of arch ratio for inclusion in the HIGH ARCH and LOW ARCH group. The arch ratio was obtained as the height of the medial arch divided by the subjects truncated foot length. If the arch ratio value were fallen between 0.22 - 0.31 then it was considered as normal arch. If values were less than 0.22 then it was considered as low arch and if values more than 0.31 then it was high arch. (Watson *et al*., 2014) [15]. The Q-angle had been measured using universal goniometer.

Results

High arch and Low arch runners' characteristics were listed and there were no statistical difference between subjects in height, weight or age. Injuries were categorized in Table 1 and 2; grouped by location. There were a total of 9 injuries in HA group and 169 in LA group.

Student's t-test shown among LA group females were having higher mean values of foot height than their male counterpart (p=0.01) and among HA group males were having higher mean values of arch height-length ratio than females (p=0.02). One way ANOVA showed significant differences in variables like Right Foot length, Ratio, Left Foot height, Left Foot length, Ratio, Q-angle Right, Q-angle Left between males and females of different group of High arch and Low arch and normal runners. (p=0.001).

Table 1: Injury distribution of high arch and low arch runners in back, hip/groin and thigh region

Conditions	Total	Low Arch	High Arch	Bony/Soft	Medial/Lateral
BACK					
Vertebral stress fracture	0	0	0	B	
Strain	4	4	0	S	
Others	22	21	1	B,S	
Total	26	25	1		
HIP/GROIN					
Groin strains	17	17	0	S	M
Greater tronchanteritis	0	0	0	S	L
Others	3	3	0	B,S	M,L
Total	20	20	0		
THIGH					
Hamstring strains	16	15	1	S	M,L
Adductor strains	8	8	0	S	M
Others	3	3	0	B,S	M,L
Total	27	26	1		

Table 2: Injury distribution of high arch and low arch runners in knee, ankle and foot region

Conditions	Total	Low Arch	High Arch	Bony/Soft	Medial/Lateral
KNEE					
Patella-femoral pain	15	15	0	B,S	M,L
Patellar tendinitis	5	5	0	S	M,L
IT band friction syndrome	7	7	0	S	L
MCL sprains	8	7	1	S	M
Quadriceps tendinitis	5	5	0	S	M,L
Others	5	5	0	B,S	M,L
Total	45	44	1		

Others	1	1	0	B,S	M,L
Total	21	21	0		
ANKLE					
Medial ankle sprain	2	2	0	S	M
Laretal ankle sprain	6	3	3	S	L
Achilles tendinitis	2	2	0	S	M,L
Others	9	8	1	B,S	M,L
Total	19	15	4		
FOOT					
Plantar Fasciitis	7	6	1	S	M,L
Meta-Tarsal Stress Fracture	1	0	1	B	M,L
Sesamoiditis	2	2	0	B,S	M
1st MTP Joint Sprain	5	5	0	B,S	M
Others	5	5	0	B,S	M,L
Total	20	18	2		
GRAND TOTAL	178	169	9		

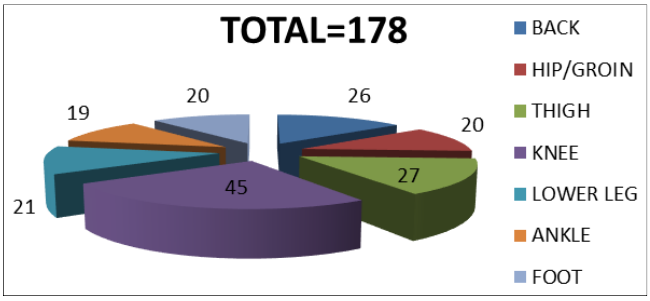

Fig 1: Different injuries of back and low extremities in high and low arch runners

Table 3 represented the descriptive statistics of anthropometric variables, foot arch height and Q-angle in male and female normal foot arch runners. In normal foot arch male runners, anthropometric variables i.e. height, weight, BMI, right foot length, left foot length showed the higher mean values than the female counterpart with statistically no significant differences. In normal foot arch male runners the foot arch height and Q-angle measurements- right and left foot arch height showed higher mean values than normal foot arch female runners. In female variables like Q-angle right and left showed higher mean values than males with statistically no significant differences.

Table 3: Descriptive statistics of anthropometric variables, foot arch and Q-angle in normal foot arch male and females runners

Variables	Males		Females		t-value	p-value
	Mean	SD	Mean	SD		
Height	164.86	5.08	156.78	5.09	3.15	0.90
Weight	56.14	6.41	49.22	6.24	2.17	0.54
BMI	20.10	1.40	19.78	1.62	0.41	0.41
R.Foot height	4.59	0.60	4.17	0.37	1.78	0.23
R.Foot length	18.40	1.30	17.30	0.95	1.97	0.39
Ratio	0.24	0.030	0.24	0.02	0.02	0.32
L.Foot height	4.39	0.57	4.14	0.41	0.99	0.39
L.Foot length	18.40	1.29	17.30	0.95	1.97	0.39
Ratio	0.24	0.024	0.25	0.03	0.77	0.51
Q-Right	14.29	1.50	16.55	1.74	2.75	0.43
Q-Left	14.43	1.27	16.44	1.94	2.36	0.24

R- Right, L- Left

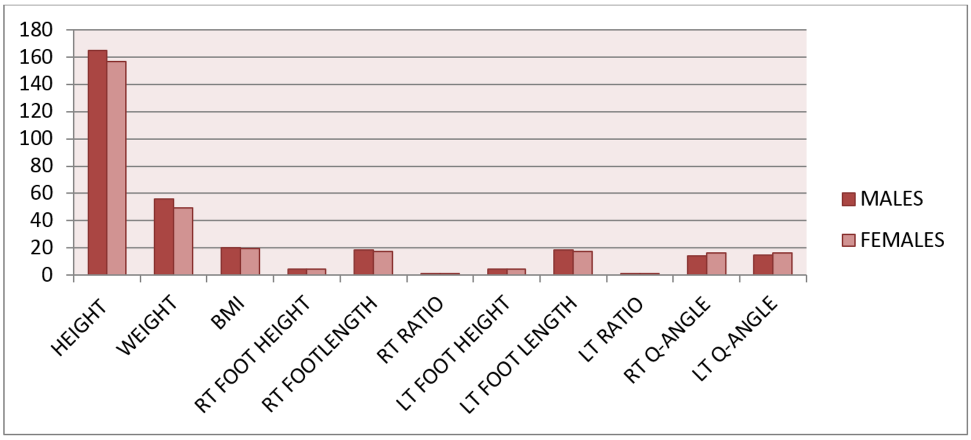

Fig 2: Graphical representation of anthropometric variables, foot arch and Q-angle in normal foot arch male and female runners

Table 4 showed the descriptive statistics of anthropometric variables, foot arch height and Q-angle in male and female low foot arch runners. In low foot arch male runners, anthropometric variables i.e. height, weight, BMI, right foot length, left foot length showed the higher mean values than the female counterpart with no statistical significance. In low foot arch runners, the foot arch height and Q-angle measurements- right foot arch height showed higher mean values in male than female whereas left foot height showed higher mean values in females than male with statistically significant differences. ($p<0.05$). Right and left Q-angle showed higher mean values in female than male with statistically no significant differences.

Table 4: Descriptive statistics of anthropometric variables, foot arch and Q-angle low foot arch male and females runners

Variables	Males		Females		t-value	p-value
	Mean	SD	Mean	SD		
Height	167.00	10.59	163.42	7.62	1.35	0.14
Weight	58.79	9.98	55.52	7.87	1.28	0.40
BMI	20.94	1.79	20.44	2.12	0.99	0.49
R.Foot height	4.06	3.57	3.64	0.44	0.51	0.34
R.Foot length	19.11	1.12	18.97	1.42	0.45	0.09
Ratio	0.19	0.03	0.18	0.05	0.27	0.32
L.Foot height	3.52	0.59	3.67	0.42	0.97	0.01
L.Foot length	19.11	1.12	18.97	1.42	0.45	0.09
Ratio	0.18	0.03	0.19	0.02	1.64	0.13
Q-Right	16.75	1.96	19.37	1.95	4.99	0.86
Q-Left	16.92	1.92	19.47	1.95	4.94	0.74

R- Right, L- Left

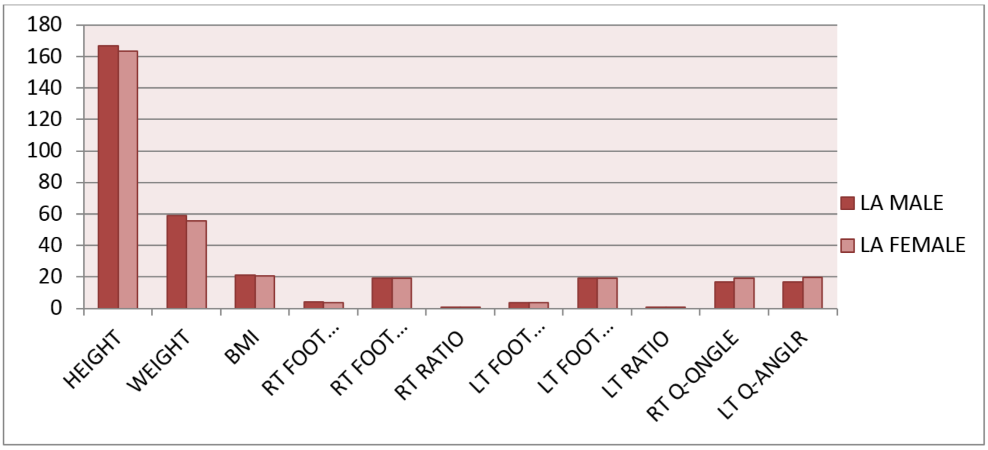

Fig 3: Graphical representation of anthropometric variables, foot arch and Q-angle in low foot arch male and female runners

Table 5 demonstrated the descriptive statistics of anthropometric variables, foot arch height and Q-angle in male and female high foot arch runners. In high foot arch male runners, anthropometric variables i.e. height, weight, BMI, right foot length, left foot length showed the higher mean values than the female counterpart with no statistical significance. In high foot arch runners, the foot arch height and Q-angle measurements- right and left foot arch height showed higher mean values in male than female. Whereas the Q-angle showed higher mean values in female than male with no statistical significance. The left foot height-length ratio i.e. left foot arch index showed higher mean values in male runners than female with statistical significance ($p<0.05$).

Table 5: Descriptive statistics of anthropometric variables, foot arch and Q-angle high foot arch male and females runners

Variables	Males		Females		t-value	p-value
	Mean	SD	Mean	SD		
Height	171.83	9.02	157.80	4.71	3.12	0.15
Weight	62.17	17.02	46.00	2.55	2.08	0.13
BMI	20.78	3.45	18.50	1.42	1.38	0.29
R.Foot height	5.93	0.40	5.70	0.49	0.94	0.88
R.Foot length	18.27	0.77	17.58	1.00	1.29	0.38
Ratio	0.32	.012	0.32	0.01	0.04	0.89
L.Foot height	5.93	0.42	5.68	0.37	1.05	0.68
L.Foot length	18.27	0.77	17.58	1.00	1.29	0.38
Ratio	0.32	.01	0.25	0.14	1.20	0.02
Q-Right	12.17	1.17	12.40	1.01	0.33	0.99
Q-Left	11.67	0.82	12.80	1.48	1.61	0.38

R- Right, L- Left

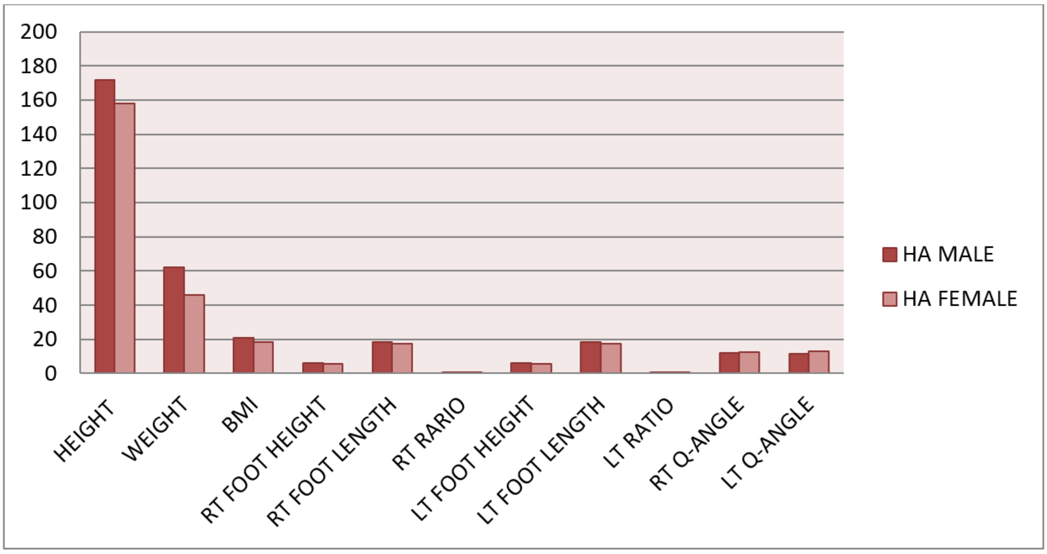

Fig 4: Graphical representation of anthropometric variables, foot arch and Q-angle in high foot arch male and female runners

Table 6 showed one way analysis of variance of anthropometric variables, foot arch height and Q-angle in male and female normal, low and high foot arch runners. Highly significant differences were found for right foot length (F= 11.32), right foot arch ratio (F= 106.01), left foot height (F= 92.1), left foot length (F= 11.32), left foot arch ratio (F= 43.83), right Q-angle (F= 29.34), left Q-angle (F=33.54) respectively.

Table 6: One way ANOVA of normal, high and low foot arch male and female runners.

Variables	F	Significance
Height	1.95	0.148
Weight	2.21	0.115
BMI	2.83	0.064
R.Foot Height	2.62	0.078
R.Foot length	11.32	0.000
Ratio	106.01	0.000
L.Foot height	92.10	0.000
L.Foot length	11.32	0.000
Ratio	43.83	0.000
Q-Right	29.34	0.000
Q-Left	33.54	0.000

R- Right, L- Left

Discussion

LA runners were reporting more medial injuries and HA runners showing more lateral injuries. It appears that the pronated position of the foot often associated with a planus foot creates increased stress on the medial structures of the lower extremities. HA runners reported more meta-tarsal stress fracture than LA runners. LA runners are showing more bony injuries than HA runners, which are contradicted the findings reported by Williams III *et al.* (2001) [16]. In this study the more bony injury found in LA groups may be due to the inappropriate training surface.

Both groups of runners reported a large number of soft tissue injuries. In fact the four most common injuries in both groups were all related to soft tissue type. This is consistent with as reported by James *et al.* (1978) [8], who reported five of the six most common injuries as being related to soft tissue.

In this present study the LA groups reported more numbers of medial side of the lower extremity injuries than the HA groups. The increased pronation of the foot leads to over stress on the medial structure of the foot. The most common injury patterns in ankle in LA groups were plantar fasciitis and 1st MTP joint sprains. LA runners reported more number of tibial stress syndrome than HA runners. The increase foot pronation causes greater transmission of ground reaction force to the tibia thus leads to increase stress on tibia. It may be due to the hard training surface and inappropriate footwear. Due to increased eversion excursion and increased pronation, in this study LA runners showed more number of medial ankle sprains and Achilles tendinitis.

LA runners reported greater incidences of posterior tibialis tendinitis as HA runners. Although the numbers of incidences are too small to draw a specific conclusion. The posterior tibialis has been shown to be a major decelerator of pronation during stance. Further evaluation of HA and LA individuals with posterior tibialis tendinitis may further clarify this relationship. The increased number of lateral injuries in the HA subjects may be partially related to increased lateral loading on the foot as the centre of pressure remained more lateral throughout the stance in HA runners.

When comparing arch height between men and women, results vary between studies. The results of this study are not consistent with the study by Frey *et al.* (2000) [3] who reported that women presented with flatter feet than men did. In this study in LA runners, the height of left foot arch has more mean value than the males. Where in right foot, more mean values in male than female. But when we compared the HA foot arch runners the left foot arch ratio has higher mean value in male than female with highly significant. Hashimoto *et al.* (2004) [7] who used radiography, a more reliable measurement method, to verify arch height in young adults also noted that the women had lower arches than the men. Structural changes in the female body may lead to pronation of the foot. Compared to men, women have narrower shoulders, hips are in a more varus position, and knees are in a more valgus position, which induces a pronation of the rear feet.

The internal rotatory stress or position of excessive internal rotation of the leg may result in several possible problems around the knee, including excessive angulations of the patellar tendon. Several obligatory motions are seen in the closed kinetic chain reactions of the lower extremity. These reactions can occur distal to proximal or vice versa, and their obligatory motions include pronation that leads to tibial internal rotation that leads to knee valgus and flexion that leads to hip internal rotation and thus Q-angle increases. In our study, low arch runners were having higher Q-angle range than the normal groups and this is same as reported by Letafatkar *et al*. (2013) [10].

Conclusion

Based on these results, high arch and low arch foot structure is associated with different lower extremities injuries pattern in runners. Range of Q-angle changes according to foot structure types. Significant differences are seen in arch height in LA males and females and arch index in HA males and females runners

Suggestion

Considering the findings of the present study, runners with arch of foot deformity may be suggested to adopt corrective exercises program to avoid lower extremities abnormalities. Different injury patterns are present in individuals with extreme high arches when compared to those with extreme low arches. Based on their predisposing foot structure these relationships may lead to improved treatment and intervention strategies for runners. Moreover, in rehabilitation phase of an injured player, regular checking of foot alignment will provide proper information towards treatment strategy. With the findings of the present study, coaches may arrange corrective devices as well as corrective exercise for the players as per their lower extremities alignment for performance enhancement and educate the sports persons to avoid various types of sports injuries.

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